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THE NEW MADRID EARTHQUAKE[1]

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GENERAL STATEMENT

Several papers, recently published, have shown an awakening interest in the region called the "sunk lands" in southeastern Missouri and northeastern Arkansas, which, as an older writer has stated, presents one of the few examples on record of the incessant quaking of the ground for several successive months far from any volcano; but so far as the present writer has been able to find, no theory or suggestion as to the probable cause of the violent phenomena exhibited in the region of New Madrid, either at the time of, or subsequent to, the period of greatest violence, has been proposed.

During the summer of 1904 the present writer had an opportunity, in connection with an investigation of the artesian waters of Missouri for the United States Geological Survey, to make several trips into the region, in one of which he was accompanied by Mr.

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[1] Published by permission of the director of the U. S. Geological Survey.

M. L. Fuller, under whose general direction the study of the artesian waters was conducted. The trips presented numerous opportunities for the observation of earthquake phenomena, often still clearly visible, and for studying their possible connection with artesian-water conditions. It is with a view to calling attention to this relation that the present paper is prepared.

PHENOMENA OF THE EARTHQUAKE

All writers on this subject refer to the earthquake as having been widespread in the then thinly settled region of the Mississippi basin, and express surprise at the exhibition of such violent phenomena occurring so far from the seacoast or volcanoes, and so distant from regions where the earth's crust is known to be in an unstable condition.

Description of the earthquake.—The circumstance of the earthquake has been graphically described by various observers, and an excellent collection of statements in regard to it has been published by Dr. G. C. Broadhead.[1] In order that the phenomena may be more vividly recalled by all, we quote from these extracts:

> A letter from L. Bringier, which had been published in the *American Journal of Science, Vol. III, 1821*, states that the shock was felt for 200 miles around. There seemed to be a blowing out of the earth, bringing up coal, wood, sand, etc., accompanied with a roaring and whistling produced by the impetuosity of the air escaping from its confinement, which seemed to increase the horrid disorder of trees being blown up, cracked, and split, and falling by thousands at a time. The surface settled, and a black liquid rose to the belly of the horses, which stood motionless, struck with panic. Afterward the whole surface remained covered with holes, which resembled so many craters of volcanoes, surrounded with a ring of carbonized wood, and sand which rose for about 7 feet. A few months after, these were sounded and found to exceed 20 feet in depth. Now it is covered with ponds and sand hills or monticules, which are found where the earth was formerly lowest. There seemed to be a tendency to carbonization in all vegetables soaking in the ponds, produced by these eruptions. A lake was produced 27 miles west of the Mississippi, with trees standing in the water 30 feet deep.

Another interesting account[2] of the earthquake is given by Godfrey LeSieur, an old inhabitant of New Madrid County. He says that—

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[1] *American Geologist*, August, 1902.

[2] Switzler, *History of Missouri*, and Campbell, *Gazetteer of Missouri.*

The first shock came at 2 A. M., December 16, 1811, and was so severe that big houses and chimneys were shaken down, and at half-hour intervals light shocks were felt until 7 A. M., when a rumbling like distant thunder was heard, and in about an instant the earth began to totter and shake so that persons could neither stand nor walk. The earth was observed to roll in waves a few feet high, with visible depressions between. By and by these swells burst, throwing up large volumes of water, sand, and coal. Some was partly coated with what seemed to be sulphur. When the swells burst, fissures were left running in a northern and southern direction, and parallel for miles Some were 5 miles long, 4½ feet deep, and 10 feet wide. The rumbling appeared to come from the west and travel east. Similar shocks were heard at intervals until January 7, 1812, when another shock came as severe as the first. Then all except two families left, leaving behind them all their property, which proved to be a total loss, as adventurers came and carried off their goods in flat boats to Natchez and New Orleans, as well as all their stock which they could not slaughter. On February 17 there occurred another severe shock, having the same effect as the others, and forming fissures and lakes. As the fissures varied in size, the water, coal, and sand were thrown out to different heights of from 5 to 10 feet. Besides long and narrow fissures, there were others of an oval or circular form, making long and deep basins some 100 yards wide, and deep enough to retain water in dry seasons. The damaged and uptorn country embraced an area of 150 miles in circumference, including the old town of Little Prairie [now called Caruthersville], as the center, a large extent on each side of Whitewater, called Little River, also both sides of the St. Francis in Missouri and Arkansas. Reelfoot Lake, in Tennessee, sank 10 feet.

Features of the earthquake area.—This disturbed area extends from a point south of Cape Girardeau for 200 miles to a locality north of Wynne, Ark., and reaches from the eastern bluffs of the Mississippi to the foothills of the Ozarks a distance of from 30 to 40 miles. It includes most of Lake County, Tenn., a number of counties in southeastern Missouri, and several in northeastern Arkansas. Dr. W J McGee, in his paper on "A Fossil Earthquake," states that—

> With a single exception, the traveler by steam packet on the lower Mississippi finds the river flanked by alluvial banks so low that during great freshets they are overflowed all the way from Cairo to the Gulf, save where protected by natural or artificial levees.

The exceptional area he describes as a low dome, which bulges upward 20 or 25 feet above the general level of the alluvial plain. This dome

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[1] *Bulletin of the Geological Society of America*, Vol. IV, pp. 411–13.

is made up of a series of more or less parallel ridges, swamps, and shallow lakes. Where the Mississippi River cuts through it the banks exhibit large deposits of sand and alluvium underlaid by a thick bed of tenaceous blue clay—the Port Hudson clay. Not only is an unconformity exhibited between the alluvium and clay deposit, but from New Madrid nearly to Osceola the bed of clay has an irregular, wave-like outline, and in places is abruptly faulted. Stumps are frequently seen imbedded in it, occasionally in a series, one above the other, extending from below low-water mark to a height 25 feet above that mark.

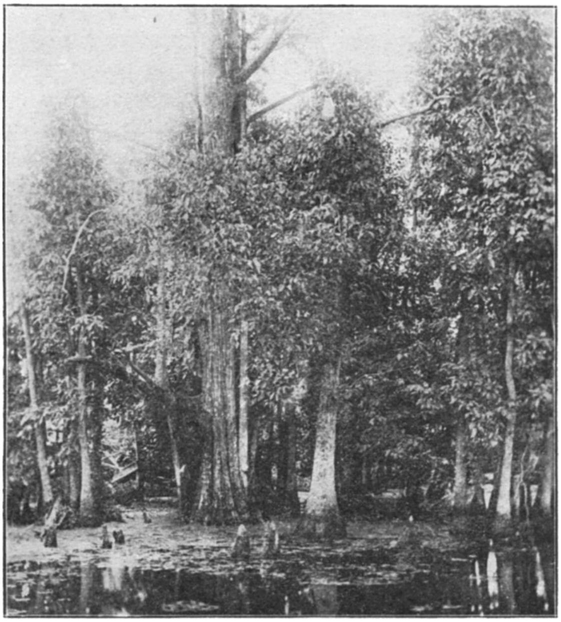

FIG. 1.—View on swamp bordering Varney River, near Kennett, Mo. (Photographed by M. L. Fuller.)

McGee calls attention, in his paper, to the dry bayous that squarely and obliquely enter Reelfoot Lake—a sunken lake in Tennessee, saying that "when this occurs there is no sign of delta-building, and both channels and natural levees may be traced long distances in the lake." He also says: "This absence of deltas indicates that the uplift or deformation occurred suddenly."

A careful study of the whole district of the dome indicates that it has been lifted above the general alluvial plain of the Mississippi. We have spoken of the narrow, more or less parallel, ridges, alternating with narrow, irregular lakes and swamps. Frequently the line between the swamp and ridge is abrupt and terrace-like. Near Gayoso a striking example of this configuration occurs. Here the general level of the ridge breaks abruptly in a straight line, and drops some 4 or 5 feet to the general level of the swamp, forming what even the countryman recognizes as a fault scarp, and describes as "the place where the land sunk."

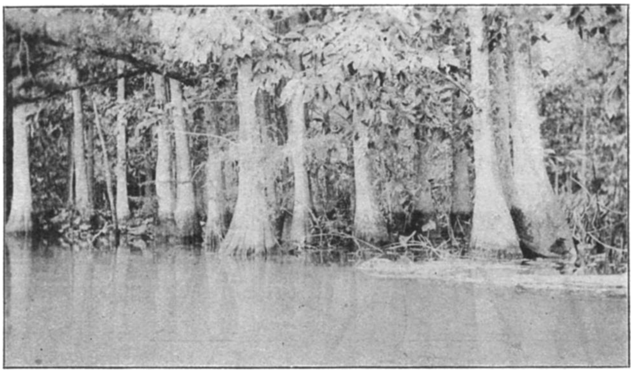

FIG. 2.—East side of Varney River, below Kennett, Mo. (Photographed by M. L. Fuller.)

The streams which flow through this district are very tortuous and generally, though not always, follow the line of the swamps. Instead of flowing into the Mississippi, they usually flow at a slightly divergent angle, and empty into the St. Francis. There is a strong and decided slope southwestward through this area from the Mississippi to the White River, the valley of the latter being there decidedly lower than the valley of the Mississippi. A large amount of water flows southwestward through this area, and it is noticeable that, while the vegetation has the characteristic luxuriance of the swamps, the water is relatively clear, pure, and cool, and alive with bass and other game fish supposed to inhabit only those waters which are moderately pure and cool. It is further remarkable that the bottoms of these streams are usually hard and sandy, with little or no muck, as is usually so common in swamps.

The elongated lakes are, as a rule, shallow, although there are some exceptions. Reelfoot Lake, in Tennessee, for example, is from 20 to 25 miles long, and from 4 to 5 miles wide, with a depth of from 20 to 30 feet. Its area is perhaps doubled in time of high water. It is deeper at the northeast than at the southwest end. The water of this lake, as well as of the others in the area under consideration, is clear and pure, and not yellow and turbid, like the waters of the Mississippi. On this lake one may float over submerged treetops, and on Golden Lake, near Wilson, Ark., as well as on others in the district, the same submergence of trees may be observed. Tyronza and Crooked Lakes are both sunken lakes fed from below by clear and relatively cool water, Crooked Lake being irregular in depth, with many deep holes in the bottom. Mr. C. B. Bailey, of Wynne, Ark., to whom the writer is indebted for personal guidance through a portion of this district and for many valuable notes, states that Little Black Fish Lake, near Parkin, Ark., 1 mile long and 200 feet wide, has a depth of from 50 to 60 feet. The water is clear and cool, and hunters sink their venison into it for preservation. Other lakes in the vicinity are shallow, being only from 5 to 15 feet deep. It is noticeable that these sunken lakes vary decidedly in the amount of subsidence. Maximum amounts are found in Reelfoot and Crooked Lakes, where the forests are entirely submerged. In others we find the timber but half-buried, and in still other instances the surface is lowered but a few feet. Several miles west of Kennett, in the swamps on the Varney River, the line of sinking is marked in a most interesting way. To the east of a north-and-south line at one point in the swamp, the timber grows tall and erect, in its normal position, while on the west it appears to be submerged to a depth of from 10 to 15 feet. There are areas where the land has been sunken, the timber killed, and the depression partially refilled with flood deposits, upon which has sprung up a new vegetation of a character entirely different from the old. In the Big Bay district, north of Wynne, Ark., the dry bayous are covered with stunted trees of willow and honey locust, while on the slightly higher land on either side are the giant cypresses and gums.

Fault scarps.—The fault scarps are a striking feature of the country, especially in the Big Bay district. Two nearly parallel lines of cracks having an east-and-west trend are found near the mouth of Fortune Creek, where it empties into the St. Francis. Others in the same vicinity have a northeast-and-southwest trend, with a present depth of about 4 feet. One of these cracks, illustrated in the photograph (Fig. 3), has growing from it a tree which is probably seventy-five years old.

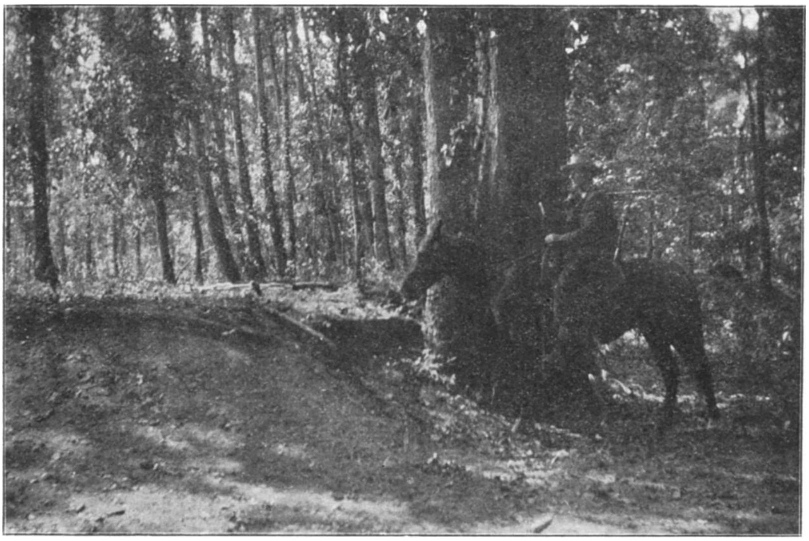

FIG. 3.—Fault scarp, ten miles north of Parkin, Ark., in the Big Bay district.

Ejection of sand.—Another feature of this region, and one which will be referred to later, is the large amount of white sand that constitutes the surface of the New Madrid district. Passing down the Mississippi River from St. Louis, the amount of sand on the banks is not relatively large. On entering the sunken district, we find a small amount of coarse sand, which is evidently derived from the breaking down of the Ordovician and Cambrian sandstones of the country above, and proceeding southward we find a steady increase in the amount of fine white sand which, everywhere forms the surface of the flats, reaching a maximum thickness in what is called the "sand slew" country, at the southern end of the area under discussion, 20 miles north of Wynne. The land here is frequently too poor to support much vegetation. There is little or no loam, and arid patches of sand are common. Along the edges of the cracks and fault scarps large deposits of sand are frequently found. Another peculiar feature of the country which should be mentioned is the presence of "sand blows"—low mounds of fine white sand mixed with small pieces of lignite. These mounds are 3 or 4 feet high, with a diameter of from 20 to 100 feet, and are frequently slightly hollowed in the center. They are scattered over the whole district, and the sand is so pure that it will not support vegetation, and consequently barren patches mark their site.[1]

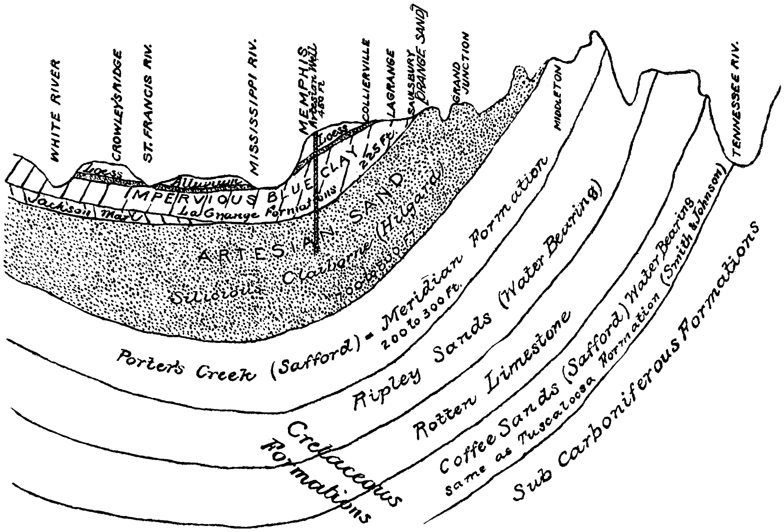

FIG. 4.—An east-and-west geological section through Memphis, Tenn. Vertical scale exaggerated about 250 times. The Orange Sand (LaFayette formation) lies between the Artesian Sand and the Impervious Blue Clay of the diagram. (From J. M. Safford's report to the Artesian Water Co., of Memphis, Tenn.)

ASSOCIATED ARTESIAN CONDITIONS

The Mississippi Valley forms a strong artesian basin between the Tennessee Mountains and the Ozarks. Referring to the geological section and map adapted from the report on *The City Water Supply of Memphis*, by Safford, it will be noticed that loess covers

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[1] The inhabitants claim that wells driven in these "sand blows" give a better quality of water.

Crowley's ridge on the west, and the bluffs on the east side of the valley, while sand and alluvium cover the area under discussion. Beneath the loess is from 6 to 40 feet of Lafayette gravel, followed by a layer of impervious blue clay—the La Grange formation, which varies greatly in thickness, and averages from 100 to 225 feet. Under this impervious blue clay is from 10 to 40 feet of Orange sand, and below this is found the great water-bearing sand, the Silicious Claiborne, or the La Grange sand of the La Grange formation of Hilgard, which varies in thickness from 600 to 800 feet. This deposit of sand, which is finer in texture above and below than in the middle, and which is intercalated with thin beds of clay and a considerable amount of lignite, is a reservoir in which the waters from the Tennessee Mountains and the Ozarks meet under great pressure. Beneath this sand is found from 200 to 300 feet of Porter's Creek (Safford), or Meridian, formation, and under the last is about 250 feet of Ripley sands, another water-bearing formation, the source of the artesian waters of Jackson, Miss., while still lower is the Rotten limestone overlying the Coffee sands, which, in turn, rest unconformably upon the Sub-Carboniferous.

Numerous drill-wells through and around the sunken district develop the fact that the wells of the region do not flow, but that the water rises to or very near the surface, while those on the border of this district are mainly artesian, or flowing, wells. Starting at Memphis, where there are 140 flowing wells, and going northward along the border of the district, a flowing well 628 feet deep is encountered at Dyersburg, Tenn.; one 840 feet, at Hickman, Ky.; one 930 feet, at Wystaff, Ky.; several over 800 feet, at Cairo, Ill.; one 626 feet, at Mound City, Ill.; one 710 feet, at the mouth of Cash Creek, Ill.; one 62 feet, at Pocahontas, Mo., north of Cape Girardeau; one 900 feet, at Campbell, Mo.; and one 480 feet, at Parkin, Ark., west of Memphis.

In the sunken area which is encircled by these flowing wells there are non-flowing wells at Terrell, Ark., 860 feet; north of Memphis, 800 feet deep; at Deckerville, Ark., 700 feet; at Caruthersville, Mo., 428 feet; at New Madrid, Mo., 200 feet; and at Sikeston, Kennett, and Marked Tree, Mo. The waters in the flowing well at Cairo are probably derived from the St. Peter's sandstone.

Here we find the anomalous condition of a great artesian basin where the wells flow in a circle surrounding the center, but rise to the surface only on the low ridges within this circle. The constant and vast seepage along fault lines and low places, accomplished by springs to be later described, keeps down the stronger artesian pressure which is seen on the outer borders of the area.[1]

Sand brought up in wells.—Messrs. W. G. Lanhan and W. C. Davis, engineers for the Memphis Water Co., state that of 141 wells that have been sunk in Memphis nearly all flow when they are not pumped, and that the altitude to which the water rises, when not pumped, is 218 feet above Biloxi, Miss. These gentlemen both say that there is a continuous flow of fine sand carried up to the surface by the water of all these wells from depths varying from 450 to 600 feet. A brass strainer, with openings one hundred-and-fiftieth of an inch in width, is placed in the bottom of each well, and this is so rapidly worn by the sand that it has to be replaced in from three to five years. Every precaution is taken to keep this sand from the valves and piston rods of the pumps. The wells are tapped at depths of from 40 to 60 feet, and the water is conveyed by large brick tunnels 5 feet high to a central reservoir well at the pump station. The sand collects so rapidly in these tunnels that they must occasionally be cleaned out. One tunnel was found nearly filled with sand deposited from the water.

Mr. Henry Moss, of New Madrid, Mo., was connected with the Missouri River Commission some twenty-five years ago, when a series of wells was sunk along the river and on the islands from Lister's Island, 20 miles north of New Madrid, to Fort Pillow, near Osceola, Ark.—a distance of about 90 miles. These wells were bored from 125 to 200 feet deep, and he states that the sand and water would shoot up into the pipes to within 30 feet of the surface, the sand frequently clogging the bottom of the pipe.

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[1] The writer is greatly indebted to Mr. W. B. Johnson, of Memphis, Tenn., for various sections and data relating to the wells of this district. He calls attention to the similarity in composition of the waters on the east side of the basin; also to the purity of these waters, which undoubtedly have their source in the Tennessee Mountains. These are in striking contrast to the waters on the west side, which are generally saline, and which have their source in the Ozarks. He further states that the La Grange sands at Memphis are 800 feet thick, while at Pine Bluff, Ark., they are only 40 feet.

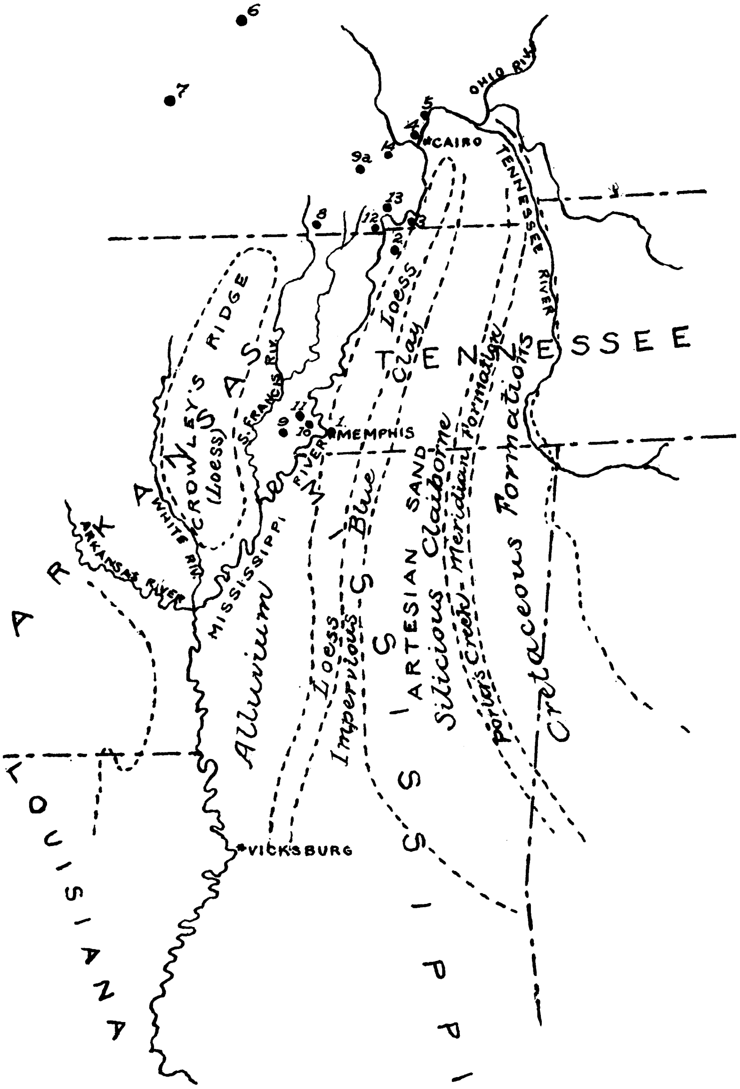

FIG. 5.—Plan showing the outcrop of geological strata east and west of Memphis. Scale: 1 inch = 90 miles. (Adapted from J. M. Safford's report to the Artesian Water Co. of Memphis, Tenn.) Flowing wells occur as follows: (1) Memphis, Tenn.; (2) Dyersburg, Tenn.; (3) Hickman, Ky.; (4) Cairo, Ill.; (5) Mound City, Ill.; (6) Pocahontas, Mo.; (7) Grandin, Mo.; (8) Campbell, Mo.; (9) Parkin, Ark.; and non-flowing wells at (10) Terrell, Ark.; (11) Deckerville, Ark.; (12) Caruthersville, Mo.; (13) New Madrid, Mo.; (14) Sikeston, Mo.

Sand brought up by springs.—We have noted the character of the water in the sunken lakes and streams—its clearness, purity, and temperature—and that the streams, where sounded, seem to have a hard, sandy bottom, and a general absence of muck. We have further referred to the great volume of pure water that is everywhere flowing out of this sunken district, and also to the abundance of game fish which only thrive in pure spring water. That typhoid fever is almost wholly unknown in this district is another fact bearing on the purity of its water supply. The people drive a pipe with a strainer 10 or 15 feet into the sand, and obtain an abundance of reasonably pure water, which they pump to the surface.

A careful study of these streams, especially along the St. Francis, the Little Tyronza and the Big Bay, reveals the fact of the constant escape of water from below through small openings surrounded by little cones of sand. This is noticeable for miles along the St. Francis and in the Big Bay district, especially on the bluff side of the streams.

Deep-seated water, then, is constantly coming to the surface, bringing with it fine sand from below. It is probable that old fault lines through the clay permit this constant discharge, which must slowly and steadily produce an undermining of the clay layer by the removal of the sand below. A glass of water taken from the springs, though seeming quite clear, will deposit, in a few minutes, a fine film of sand at the bottom. Mixed with the little sand-cones that surround the spring outlets are minute particles of lignite, which further indicate the deep source of these waters.

The soil is generally very thin, especially in the southern part of this district, where the sand deposit is thicker, and the surface sand, for several inches, is destitute of the fine particles of lignite, the absence of which is partly due to the action of surface waters in carrying the lighter particles away. Earthworm castings, however, wherever found, show the presence of the lignite. This sand that is spread over the greater portion of the sunken district, in size of grain, structure, general appearance, and association with lignite, closely resembles the drill samples obtained from the Silicious Claiborne, or La Grange formation, and justifies the conclusion that it has been thrown up from below.

A careful microscopical study of these sands confirms this impression. Under the microscope we find them to be made up of varying mixtures of small, beautiful, rounded, incoherent, water-worn grains of quartz, ranging from limpid or pellucid to perfectly transparent, glass-like particles. Occasionally, rounded grains of red, yellow, or black jasper occur, and in all samples fragments of lignite are seen. The samples studied were obtained from the artesian wells at Memphis, the small springs scattered over the district, the fault scarps, and many localities throughout the whole sunken area. The apparent identity of the surface and artesian sands is very plain.

Source of sand covering surface of "sunk area."—Testimony from various witnesses establishes the source of much of the sand distributed over this area. Eliza Bryan, of New Madrid, in a letter to Lorenzo Dow, dated March 22, 1816, speaks of the awful darkness of the atmosphere, which was saturated with sulphurous vapor, and of the fact that during all the hard shocks the earth seemed horribly torn to pieces, while the surface of hundreds of acres was from time to time covered over, for various depths, with the sand that issued from the numerous fissures. She says: "Some of these fissures closed up immediately after they had vomited forth sand and water. What seemed to be coal was thrown up with the sand in some places." A. N. Dillard, of New Madrid, stated to Professor J. W. Foster that the shocks continued from twenty to thirty months, and that in every instance the motion was from the west or southwest. He said: "Fissures would be formed from 600 to 700 feet long, and 20 to 30 feet wide, *through which water and sand spouted 40 feet high.*"[1]

Mr. Timothy Flint published in his *Book of Recollections* that "a tract near Little Prairie, now called Caruthersville, became covered with water 3 or 4 feet deep, and when the water disappeared there remained a stratum of sand." Further, that "there were two classes of shocks—those in which the motion was horizontal, and those in which it was perpendicular."

In the description by Godfrey LeSieur, given on a previous page, attention is called to the large volume of water, sand, and coal that was thrown up. Dr. Hildreth, in Wetmore's *Gazetteer of Missouri*, states that—

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[1] Italics are the writer's.

> The earth on the shores [of the Mississippi River] opened in wide fissures, closing again, and water and mud, in huge jets, were thrown higher than the treetops. The atmosphere was filled with a thick vapor or gas. . . . . The sulphurous gases discharged during the shocks tainted the air, and the river water, for 150 miles below, could not be used for a number of days.

Hon. Lewis F. Linn, of the United States Senate, states in a letter concerning this earthquake that "the earth rocked to and fro, vast chasms opened from which issued columns of water, sand, and coal, accompanied by hissing sounds."[1]

To sum up the testimony of most observers, we have emphasized the fact that the disturbance came from the west; that the ground rolled in great waves; that numerous fissures were formed; that great volumes of "sulphurous vapors," water, sand, and lignite were thrown up at various heights; that large areas were covered with water, the subsidence of which was marked by a thick coating of sand; that these shocks continued for nearly three years; and that the waters of the Mississippi receded for several minutes.

Further, we find today that large volumes of water are constantly coming to the surface as springs in this district; that these springs are numerous along the lines of fissure; that deep artesian wells around this region bring up this same variety of sand with lignite, some, as at Memphis, when first sunk, ejecting large chunks of the lignite; that the sand and lignite brought up in the deep wells are similar to the same substances brought up by the innumerable springs that feed the lakes and streams of this district, and that they are apparently the same as that which surrounds the blow-holes and fault scarps, and which covers, as with a vast sheet, the considerable areas in the sunken district.

Relation of the earthquake to artesian conditions.—If one studies the phenomena of the earthquake as seen by the observers quoted in this article, he cannot help being impressed with the fact that the conditions as described are identical with what would be expected to occur from the undermining of the clay horizon by the slow and continuous removal of large bodies of sand. In this process of undermining a time would come when a slight disturbance would destroy the equilibrium, and when the great pressure of the artesian water below would burst forth, causing the elastic clay roof to undulate, with the resulting earth-waves and ejections of water, sand, and lignite so vividly described by numbers of eyewitnesses of the catastrophe. The first disturbance, relieving, to a degree, the artesian pressure, would be followed by a temporary equilibrium, which would be succeeded by other periods of disturbance, as described.

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[1] The above quotations are taken from Dr. Broadhead's collection of letters and documents relating to the earthquake, published in the *American Geologist* for August, 1902.

RECENT EARTHQUAKES

This region has for many years been subject to slight earthquake shocks. A year rarely passes without their occurrence, the last one having as recent a date as September, 1904. In August, 1903, houses were shaken and dishes rattled, the phenomena lasting about ten minutes, and being accompanied by a roaring sound underneath. This earthquake was rather severe near Charleston, Mo., where a pond 3½ miles from the town was greatly enlarged by the sinking of adjacent land. The disturbance was attended by the throwing up of a considerable quantity of fine white sand. Mr. W. M. Timbs, a railroad conductor, stated that on October 5, 1895, quite a severe earthquake occurred in this region. At this time, south of Belmont, the water flowed from the driven pumps in this vicinity, and brought up sand and particles of coal, the pumps continuing to flow for a month. Numerous small cracks were formed on the prairie, from which sand and particles of coal were ejected. The writer's attention was called to the fact that one or more of these earthquake shocks occur each fall, being more frequent at that season of the year than at any other time. This might be accounted for by the low water in swamps, streams, and ponds following the dry season characteristic of the country—a condition which would give decreased pressure at the surface and offer least resistance to the artesian pressure below. Observers state that these shocks are always accompanied by a roaring noise and a waving of the ground.[1]

Some of the intense local disturbances in the Charleston, S. C., earthquake district, which is also an artesian district, may have been due to the long and slow undermining of superincumbent beds by the removal of sand by artesian pressure. Visitors to this region have informed the writer that large quantities of sand were thrown up at various places during the shocks, and that springs bringing up sand still issue from the fissures thus made, similar to those described in the Big Bay district.

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[1] Mr. W. S. Randall, of Poplar Bluff, Mo., informs the writer that in a well sunk there to a depth of 700 feet, a number of years ago, the water rose to within 15 feet of the surface. A twelve-horse-power engine could lower it only about one inch; but after a severe earthquake shock, about three years ago, the well was nearly ruined, and since then furnishes barely enough water to run a factory.

COMPARISON WITH CONDITIONS NEAR SHREVEPORT, LA.

Several visits to the region around Shreveport, made a number of years ago, revealed a condition similar to those of the New Madrid area, and suggested the probability of the agency of earthquakes in producing the lakes, swamps, and deposits of sand so characteristic of this portion of the state of Louisiana. Shreveport is likewise an artesian region, and in its geological structure is similar to that of New Madrid. Sunken lakes covering forests occur there, as described by Lyell,[1] who calls attention to these sunken lakes as illustrating the changes now in progress in the earth's crust. In the Red River region of Louisiana he mentions Lake Bistineau, which is 30 miles in length and from 15 to 20 feet deep, and on which one may float over a submerged forest. He also refers to Black, Caddo, Spanish, and Natchitoches Lakes, and does not agree with Darby's view that the gradual elevation of the bed of the Red River by the accumulation of alluvial material has raised its channel and caused its waters, in flood time, to flow up the mouths of some of its tributaries and to convert parts of their courses into lakes. Lyell says that—

> Most probably the causes assigned for the recent origin of these lakes are not the only ones. Subterranean movements . . . . have altered the levels of various parts of the basin of the Mississippi.

Mr. A. C. Veatch says in a paper on the Shreveport area:[2]

> The valley region above Shreveport is possibly unique in the respect that changes, which usually occupy great periods of time, and whose full story can only be learned by deduction, have taken place here within a few years. Lakes have been formed and destroyed; streams formed and abandoned; waterfalls produced to destroy themselves; new streams formed out of parts of the beds of old ones; and temporary reversals of the drainage system have been effected.

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[1] Lyell, *Principles of Geology*, Vol. I, p. 457.

[2] Geological Survey of Louisiana, *Report for 1899*, p. 152.

On p. 159 of this same report we read:

> Connected with Sodo Lake by Big Willow Pass is Ferry or Fairy Lake. It differs from Sodo by having hills on both sides; being exactly the same type as Cross Lake, a lake occupying an old stream valley. Ferry Lake is quite shallow, with a narrow line of deeper water winding irregularly through it. This lake is rendered particularly interesting by the large number of cypress and oak stumps standing upright in it, even in the deepest water.

The same author says further, on p. 185:

> On the recent origin of the lakes in the upper part of the valley there can be little question. A number of planters of Red River bottoms have repeated to me the old Caddo Indian tradition that about 150 years ago the land now occupied by Sodo Lake was an oak ridge, that all the water flowed in a narrow cypress-fringed bayou in the center, and that the filling of the valley was sudden, as if by an earthquake.

PRIMARY CAUSE OF THE NEW MADRID EARTHQUAKE

As to the primary cause of the New Madrid earthquake, it is difficult to make any statement. It may have been due to the readjustment of fault lines in the Ozarks, or to a similar cause in the Appalachians. It would seem more likely to have been the former, as the fault scarps in the Ozarks frequently have an appearance that does not betoken great age and, further, slight earthquake shocks, which observers described as coming from the west, have been noticed.

As to the cause of the great local disturbance in the New Madrid region, there can be no doubt that it was due to the great artesian pressure from below, which slowly undermined, for centuries, the superincumbent beds of clay by the steady removal of the sand through innumerable springs. A slight earthquake wave would destroy the equilibrium of a region thus undermined, resulting in the sinking of some areas, and the elevation of others, thus producing such conditions as were described by various observers who witnessed the castrophe of 1811.

The escape of gas resulting from decaying organic matter may have had something to do with the certain phenomena of the earthquake, and would certainly account for the presence of so-called "sulphurous vapors" and gases referred to by so many observers in their accounts of the earthquake.

CONCLUSIONS

The facts here given present an explanation of the elevation and depression of the land in the New Madrid region that has not before been recognized, and the writer believes that they form a satisfactory explanation of the phenomena which have so long puzzled those who have attempted to solve the problem of the great local disturbance at New Madrid. If this is so, they may also explain similar instances of subsidence and elevation in other regions that have been little understood, and will demonstrate, for the artesian waters of the globe, a wider influence as a geologic agent than has hitherto been ascribed to them.